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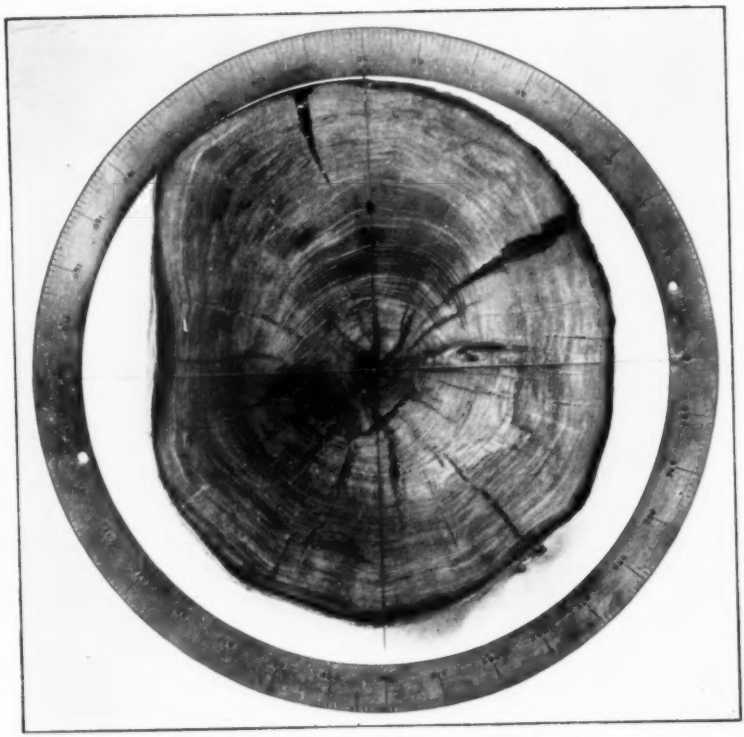
Fig. 1. (top) The "Sunken Farm" of Eugene Matteau.
Fig. 2. The "neck" through which the flow passed into the ravine.
Fig. 3. (bottom) Upper end of pit formed by landslide at Matteau Farm.

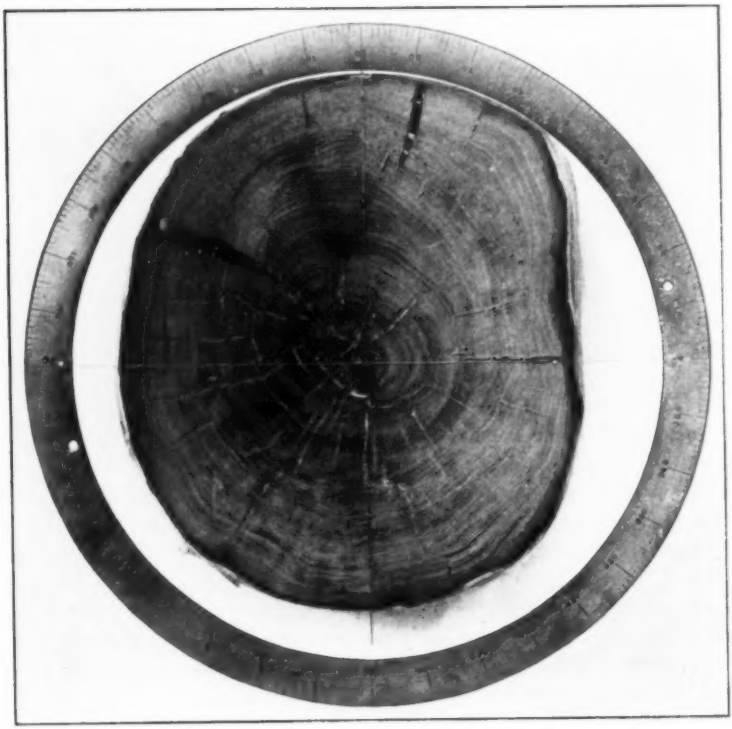
(Photos by J. W. Goldthwait for Geological Survey of Canada)

Plate VIII.



A. Upper Face of Section of Pre-glacial Spruce.

Plate IX.



B. Lower Face of Section of Pre-glacial Spruce.

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VOL. XXI, No. 7 SEPTEMBER, 1927 Whole No 167

THE MARINE CLAYS OF EASTERN CANADA AND THEIR RELATION TO EARTHQUAKE HAZARDS*

By ERNEST A. HODGSON

The St. Lawrence and Ottawa valleys have very extensive deposits of Pleistocene marine clays. These clays are, sometimes, quite impervious to moisture. An unfilled grave, dug in a clay of this type, will remain open and straight-sided for months. In some cases these impervious clays are underlain by a stratum of gravel or sand, which admits ground water beneath them. If the arenaceous stratum is inclined toward a ravine or river valley, a season of heavy rain may percolate beneath the clay, making a slippery and tilted underground surface and thus causing a landslide. For convenience such a slide may be referred to as one of the first class.

On the other hand, some of the deposits are laminated, being composed of alternate layers of sand and clay. Where the laminated clays are subjected to long periods of rain, they become like quicksand. If they border a ravine or river, an opening may be formed at a point where discharge under gravity can take place. Great quantities of the soup-like mud are thus released. The top soil may settle as much as fifty feet or more, sometimes in a single night, over areas several acres in extent. These may be referred to as landslides of the second class.

It is sometimes difficult, if not impossible, to say exactly to which class any particular landslide may belong. At other times the distinction is very well marked indeed. As an illustration of

*Paper presented at the Annual Meeting of the Eastern Section of the Seismological Society of America, at Boston, May 4–5, 1927.

the various phases of this problem, a description will be given of some slides which have been examined carefully. We may, for convenience, arrange these in chronological order. A bibliography, listing publications consulted, is appended. The numbers, in brackets throughout this paper, refer to the publications in that bibliography.

The earliest available recorded observations on a, then recent, slide appear in a paper by Sir W. E. Logan (1), which refers to a great slide on the Maskinongé river, on April 4, 1840. The paper is quoted at some length by Dr. R. W. Ells (4 and 6).

The area affected in this case was about 84 acres. The pit formed was roughly oblong in shape, with a narrow funnel-like end toward the river. It was 1300 yards long, and 600 yards wide at its point of maximum breadth. The bottom was 30 feet below the level of the surrounding country. The material, transported into the Maskinongé river, filled it to a depth of 75 feet for a mile and a half.

Evidently Logan considered this a landslip of what we have called the first class, for he assigned the cause to "pressure on an inclined plane, assisted by water". The narrow funnel-like end suggests, however, that it may have been, in part at least, of the second class.

The next clay slide of which a record was discovered was on Rivière de la Pérade, near St. Albans, on April 27, 1894. (2, 3, 4, and 6). The following notes are extracted from these papers by Dr. Ells.

The marine deposits (Leda clay and Saxicava sand) slid down bodily into the river, for a distance of three miles and a half. The slide took place in three sections, at intervals of some hours. At each slide the depth of the chasm was thereby increased. The total effect was to produce a depression whose greatest width was half a mile, and whose depth averaged 100 feet, but was, at some points, as much as 175 feet. The mass of material thrown into the river permanently changed its course.

It would seem quite likely that this slide was definitely due to pressure on an inclined plane, the various sections having been caused to slip by an infiltration of water along an inclined layer of sand within the silty clay.

The third landslide to be described took place on Rivière Blanche, a tributary of the Ste. Anne de la Pérade, near St. Casmir village, Portneuf county, on May 7, 1898. (4, 6, 7, and 8).

The superficial formations are, as previously indicated, Leda clay and Saxicava sand, together with some boulder clay. In the pit where the landslip took place the Leda clay is prolific in marine shells, chiefly Leda Arctica and Macoma Groenlandica. No well-defined break exists between the sand and the clay, the one graduating into the other. The surface water, during the period of melting snow, is thus able to penetrate to a considerable depth. An analysis showed that the clay in the pit formed by the landslide was capable of carrying, when saturated, from 22 to 25 per cent. of its own weight of water.

The pit formed was irregularly oblong, about 1050 yards long, 600 yards wide, and 28 feet deep. The figures given are for the maximum in each case. The slide took place on an inclined plane of which the gradient was but ten inches to a hundred feet. This, argues Ells, proves that the clay and sand were in a semi-liquid condition. The landslip, according to eye-witnesses, resembled the bursting of a reservoir.

The first indications were observed on May 6, but nothing was thought of it. At about 5 a.m. on May 7, the slide went out, destroying three farms with the buildings. The people fled for their lives, all escaping except one little girl who was buried in the débris. The material discharged into the valley was so great as to fill it to a depth of 25 feet or more, for a distance of nearly two miles.

One of the publications referred to (8) describes also a landslip of similar character which happened a few years previous to the one on the river Blanche. This was in the parish of St. Luc, Champlain county, along the Champlain river. It was, however, on a very much smaller scale.

The next landslide to receive attention is one on the Lièvre river, within 22 miles of the city of Ottawa, close to the village of Poupore. This occurred on Sunday morning, October 11, 1903. It is described by Ells (5).

This slide comprised an area of nearly 100 acres, of a roughly triangular shape, with a base on the river of approximately 600

yards, and a depth inland of about 800 yards. At the back of the slide location, away from the river, is a ridge of granite and gneiss, belonging to the Laurentian formation, having a slope toward the river in a north-east direction. The clay flats between this ridge and the river are nearly level.

Just previous to the date of this slide there had been several days of heavy rain. The water penetrated under the clay, along the foot of the ridge, where a layer of boulders and rock débris made the infiltration possible. The clay, rendered abnormally heavy by the rain, and resting on a sloping subsurface, slid bodily forward into the Lièvre river. The pressure was so great that the clay was pushed entirely across the stream, which, at this point, was over a hundred yards wide.

The bed of the river here, is of clay, and very slippery. Some of the rafted sections of the clay from the landslide were pushed along the smooth bed of the river and carried downstream for hundreds of yards. One of these clay rafts carried a hay barn along with it.

A road which crossed the area affected was broken and a section of it carried toward the river. Near this road was a tract of four or five acres of the original clay flat, which was moved bodily for a distance of about 200 feet, but was otherwise undisturbed.

Near this tract was a house, owned by a M. Clement. His house was moved bodily a distance of about 150 feet, being carried and deposited in an upright position. His well, near the house, was moved with it without being drained.

Not far from the river, and within the area affected by the slide, several cattle, standing on a farm roadway, were engulfed by crevasses which opened beneath their feet and then closed over them.

Ells says of this slide: "It would seem, therefore, that the real cause of this disturbance was the saturation of the clay beds, which are arenaceous in places, and then by the softening of some interstratified silty layer, which was apparently about twenty feet from the surface, the mass moved forward, sometimes in block, but generally in a much broken up condition. The movement was rapid and attended apparently with but little noise, since the residents were quite unconscious of the disaster till the disturbance was nearly over."

Within five years of the Poupore slide another occurred on the Lièvre, at Notre Dame de la Salette, about five miles farther up the river (6). This village is within the section of the upper reach of the river, which was flooded by the previous slide. The slide took place (also on a Sunday morning) April 6, 1908. It was a relatively small one, but was the most serious on record, as regards the destruction of property and of life.

A section of the south bank of the Lièvre, 1,350 feet long, 400 feet in maximum width, and about 60 feet deep, was carried bodily across the river, destroying some six acres of good farm land, more than a dozen houses, and twenty-five outbuildings. More serious than all these, however, was the loss of life—thirty-three people were killed by falling timbers, engulfed in the slide itself, or drowned by the rush of water from the river. Only about half of the bodies were recovered, some being carried down as far as Buckingham (13 miles). Several persons were rescued when nearly lifeless from smothering, and exposure in the icy water.

This slide, like the one at Poupore, was due to slippage on a substratum of porous material in the clay, the tilt of which was apparently about 20 degrees. It differs from the former slide in that fissures were formed, previous to the slide, at a distance of from 200 to 300 feet from the river. These fissures admitted the water to the underground stratum.

The ice on the river was unbroken at the time of the slide. It was broken up thereby and carried, with a rush, over the village of Notre Dame de la Salette on the opposite shore, completely demolishing everything in its course. At the same time the clay of the slide dammed the river, which thereupon burst its ice surface beyond the edge of the slide, and thus released a flood of ice and water which swept down over the wrecked village, completing its destruction and washing the débris down stream. The clay dam raised the level of the upper reach of the river by nearly ten feet, which did further property damage as far up as North Star landing.

This slide and the one on Rivière Blanche in 1898 are the only two in which loss of life is known to have occurred.

In the fall of 1924 (the exact date could not be ascertained) a landslip of considerable proportions destroyed about ten acres of the farm of Eugene Matteau, about two miles west of Shaw-

inigan Falls. No one was injured, and no other damage was done, directly or indirectly, by the slide. This was undoubtedly a land-flow rather than a landslide, and belongs to the second class, as the description will show.

The farm is flanked by a ravine about 150 feet deep at that point, but relatively narrow, which leads to the St. Maurice river, connecting with the west shore of the lower bay, below Shawinigan Falls. The slide went out through this ravine, passed into the St. Maurice river and was thus carried away. The elevation of the clay flat before the slide was 404 feet above mean sea level, according to the figures furnished by the Topographical Survey of Canada. The elevation of the mouth of the ravine, at the level of the lower bay of the St. Maurice, is 103 feet above mean sea level, as reported by the same organization.

Previous to the slide of 1924, there had been one which, long ago, left a depression some 40 feet deep, and having an area of perhaps forty acres, immediately west of the last one. This also flanks the deep ravine, but a little higher up. The sides of this old flow were well weathered down long since. A beautiful meadow covered the floor and slopes of this depression in 1924. A road has led down into it for many years. It is considered a normal part of the farm.

In the fall of 1924 a season of heavy rains came on. One morning the occupants of the farm house came out to find that a section of their farm, about 900 feet long, 400 feet wide, and 40 feet deep, had flowed out, down the ravine, and into the St. Maurice. The water of that river was whitened as far down as its mouth at Three Rivers (20 miles). The potato field, which had occupied the site of the slide, was left behind, but it had been lowered forty feet, to the bottom of the pit.

The edges of the new sink were rather sharply perpendicular. Between the old one and the new stood a narrow wall of clay, having a perpendicular face toward the new flow, a sod-covered gradual slope toward the old. The slide missed taking away the house and barns of M. Matteau by the narrow margin of about a hundred yards. (See Figs. 1 and 2). Another house, near the side of the depression, also narrowly escaped destruction.

The clay at this farm is strongly banded. It is formed of

alternate layers of silt and sand which were laid down in horizontal beds. It was reported that sea shells were very common in the clay shortly after the slide when many visited the site, but none were noted at the time the slide was first visited by the author early in 1926, or at the time of his second visit, accompanied by Dr. J. W. Goldthwait, a few months later.

Apparently the rain was admitted to this banded clay through the exposed flanks facing the old sink and the ravine. It became a semi-fluid mass which needed only a small neck-like opening toward the ravine through which to pass almost like water. (See Fig. 3).

The farmer has nonchalantly dug his crop of potatoes, cut a passage through the clay wall into the old sink, extended his roadway through the cut, and proceeded to farm the floor of his new sunken garden. In 1926 a crop of clover was growing there. It is a rough-looking garden to-day, but one has only to glance through the cut to see the cattle grazing in the peaceful confines of the old sink, and is thus able to visualize that time, in the near future, when the slide will be a forgotten episode.

In the fall of 1925 (Wednesday, October 7) a slide was reported from Portneuf station, on the property of a farmer named F. Frenette. A section of clay "300 feet long and 150 feet deep" was said to be on the move, threatening the destruction of the farmhouse. This was not investigated further, however, and no records are available as to the damage resulting.

The nine slides of which mention has been made in this paper are not by any means all that have taken place within the last century. There are indications of others, as has been pointed out in the case of the one near the St. Maurice. These slides are made possible by the intermixture of permeable material with the clay, either in the form of sand strata within the clay itself, or as layers of gravel and rock débris entering and passing below the clay beds, as in the case of Poupore. They complicate the hazard problems if the regions in which they exist are seismic. A comparatively slight shock may well serve to start off a slide, if the conditions of ground moisture and clay structure co-operate.

The places where they are likely to result in damage to life and property on a large scale are few, but this factor should be

taken into account in choosing sites for large investments. The preliminary investigation of proposed sites can be readily made, and the exact conditions known, after which they may be guarded against or avoided as found advisable. In cases where the conditions are already found to exist, a study of the clay should be made and continuous records of ground water level and rainfall should be kept. An investigation of the seismic conditions in such a place is of special importance. If the clays are found to be stratified special precautions should be taken to prevent their becoming saturated. If they are of the impervious type they should be examined as to the subsurface on which they rest. If no stratum of porous material is found, no apprehension need, as a rule, be entertained. If such a stratum exists, every care should be taken to find out its slope, its extent, and its possible connections with sources of water, and no opportunity should be neglected to prevent surface water from reaching it.

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Dominion Observatory, Ottawa, Canada.
April 23, 1927.

A RAPID METHOD FOR OBTAINING THE ELEMENTS OF A SPECTROSCOPIC BINARY ORBIT

By F. Henroteau

The radial velocity curve having been determined, the periastron point A is determined either by Schwarzschild's method,[1] or by the following process:—

Lay a piece of semi-transparent paper over the velocity curve: draw on it the mean axis and two parallel lines at right-angles to the mean axis, separated by a distance $\frac{1}{2}P$, or half the period. Also mark the point B on the mean axis, half way between the two parallel lines.

The piece of paper is then moved, keeping the mean axes in coincidence. When a position of it has been found, so that the straight line joining the two points A and C, where the two parallel lines cut the curve, passes through B, A and C must be the periastron and apastron points.

To determine which is periastron we have this criterion that the curve is for a shorter time on that side of the mean axis where the point of periastron lies.

The above construction is easily demonstrated, the difference of mean anomalies as well as of true anomalies for the periastron and apastron points being 180°.

Let A' be the projection of the periastron point A on the mean axis.

The equation of the velocity curve referred to the mean axis as axis of abscissae and AA' as axis of ordinates is

$$V = K_1 \cos (v+\omega),$$

K_1 being the semi-amplitude of the velocity curve, v the true anomaly and ω the longitude of the periastron. Then

$$\cos \omega = AA'/K_1$$

The value of ω between 0° and 180° is chosen when A is between the maximum and the minimum of the velocity curve.

[1]See for instance: Aitken, "The Binary Stars", p. 149.

Draw a line parallel to the mean axis having for ordinate $\pm K_1 \sin \omega = \pm\sqrt{K_1^2-(AA')^2}$, the sign being so chosen that this parallel line and A come on opposite sides of the mean axis.

Let D be the point nearest A where this parallel line cuts the velocity curve. Let D' be its projection on the mean axis.

The true anomaly corresponding to D is thus $\pm 90°$. We have indeed

$$DD' = K_1 \cos (\omega \pm 90°).$$

But $(A'D' \times 360°)/P$ is the mean anomaly M corresponding to D.

Knowing M, the eccentricity e is readily obtained by means of the following table:—

TABLE OF ECCENTRICITIES FOR MEAN ANOMALIES CORRESPONDING TO A TRUE ANOMALY OF 90°.

M	e	M	e	M	e	M	e
90	0 000	70	0 176	50	0 357	30	0 553
89	0 009	69	0 185	49	0 366	29	0 564
88	0 017	68	0 193	48	0 375	28	0 575
87	0 026	67	0 202	47	0 385	27	0 585
86	0 035	66	0 211	46	0 395	26	0 596
85	0 044	65	0 220	45	0 404	25	0 607
84	0 052	64	0 229	44	0 414	24	0 618
83	0 061	63	0 238	43	0 423	23	0 629
82	0 070	62	0 247	42	0 433	22	0 640
81	0 078	61	0 256	41	0 443	21	0 652
80	0 087	60	0 265	40	0 452	20	0 663
79	0 096	59	0 274	39	0 462	19	0 675
78	0 105	58	0 283	38	0 472	18	0 687
77	0 114	57	0 292	37	0 482	17	0 699
76	0 123	56	0 301	36	0 492	16	0 712
75	0 131	55	0 310	35	0 502	15	0 724
74	0 140	54	0 320	34	0 512	14	0 736
73	0 149	53	0 329	33	0 522	13	0 750
72	0 158	52	0 338	32	0 533	12	0 763
71	0 167	51	0 347	31	0 543	11	0 777

Interpolation for M can be made linearly without appreciable error to within one hundredth of a degree.

If V' is the radial velocity of the mean axis, the centre-of-mass velocity is

$$V_0 = V' - K_1 \; e \cos \omega = V' - e \; \overline{AA}',$$
$$a_1 \sin i = 13{,}751 \; (1-e^2)^{1/2} \; K_1 \; P,$$

and T, the time of periastron passage, can be read directly from the curve.

The method, applied to several orbits at the Dominion Observatory, shows an accuracy comparable to the Lehmann-Filhé's method.

Ottawa, June 1, 1927.

AMPLITUDE VARIATION IN THE RADIAL VELOCITY CURVES OF SOME BRIGHT CEPHEIDS*

By F. HENROTEAU

Studying the β Canis Majoris type stars,[1] two extreme cases are well typified by ν Eridani and by σ Scorpii.

In ν Eridani there is a considerable amplitude variation of the short period radial velocity curves (complete curve described in about six hours) but no appreciable variation of mean velocity (Fig. 1). The variation of amplitude is apparently periodic as indicated by Figure 2.

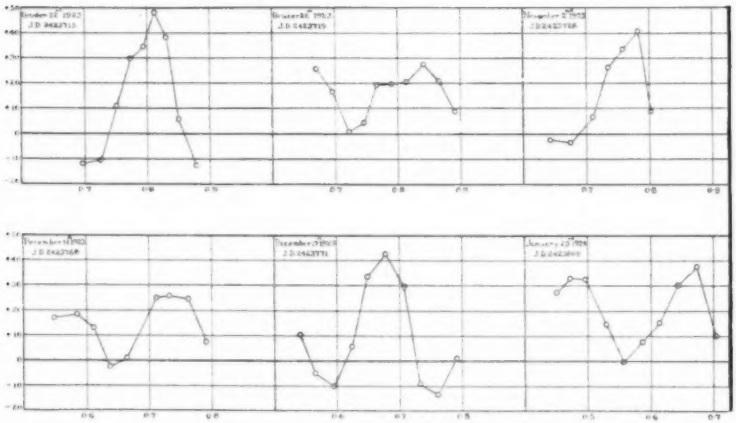


Fig. 1. Nu Eridani: Short-period Radial Velocity Curves.

For σ Scorpii the short period radial velocity curve has a nearly constant amplitude (Fig. 3) but there is a longer period variation of centre-of-mass velocity (Fig. 4).

In both cases, ν Eridani and σ Scorpii, a double periodicity is

*Read before the Royal Society of Canada, May, 1927.

[1]Publ. Dom. Obs., Vol. IX, No. 1.

thus well established; this appears general in all cases of β Canis Majoris type stars which have been sufficiently studied.

Such a double periodicity is indicated in Antalgol variables by

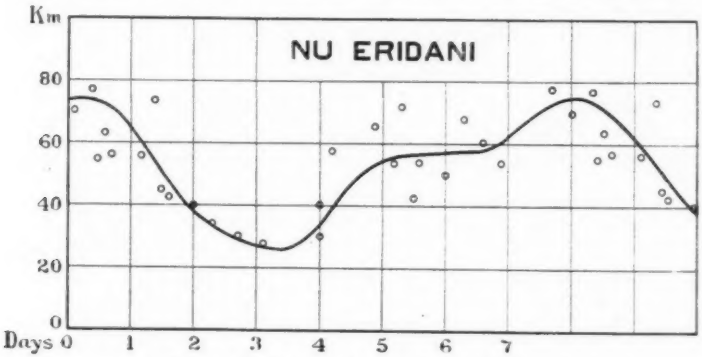


Fig. 2. Nu Eridani: Variation of Amplitude.

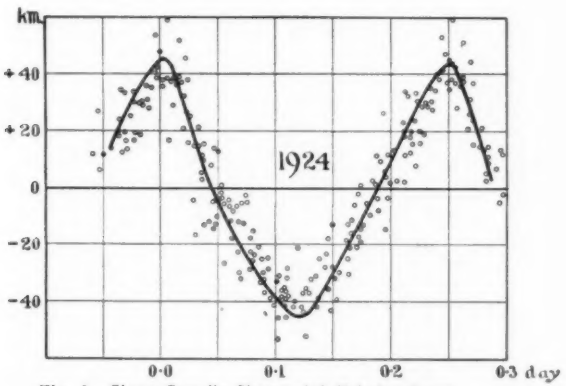


Fig. 3. Sigma Scorpii: Short-period Velocity Curve.

the change in shape and amplitude of the light-curve. Hertzsprung[2] has shown definitely that the amplitude of RR Lyrae's light-curve, as well as its period, is variable, the oscillation having an approximate period of 40.6 days. W. Baade in Hamburg found a

[2]Bul. of the Astr. Inst. of the Netherl., No. 24, 1922.

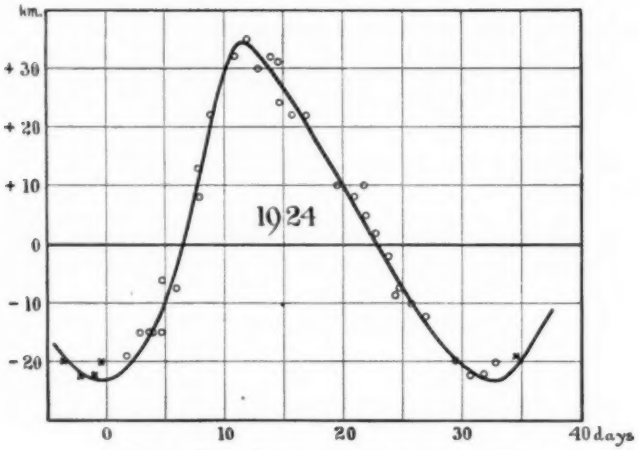


Fig. 4. Sigma Scorpii: Long-period Velocity Curve.

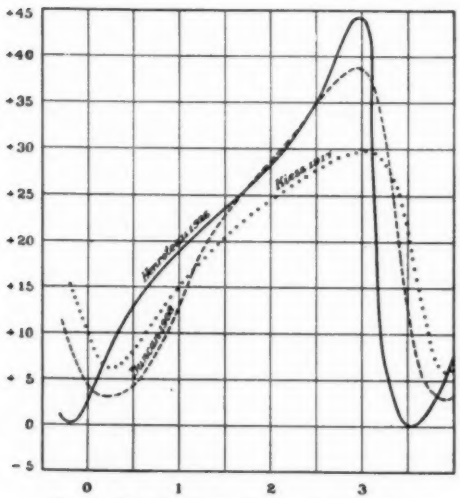


Fig. 5. Radial Velocity Curves of RT Aurigae.

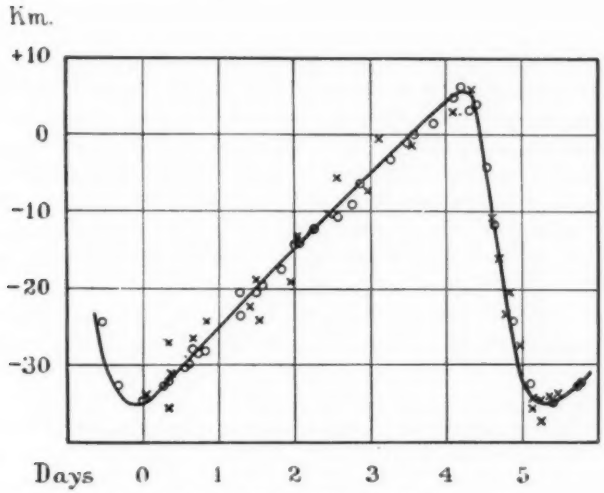


Fig. 6. Delta Cephei, Lick and Ottawa Velocities in 1923.

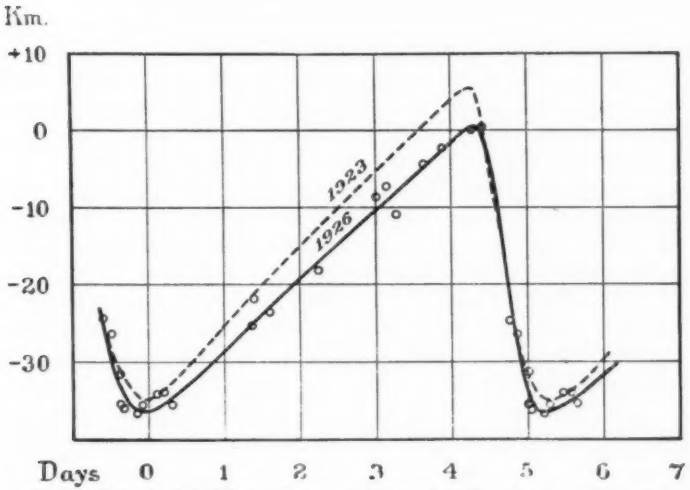


Fig. 7. Delta Cephei Velocity Curves of 1923 and 1927, with observations of 1926.

similar result for SS Cancri, and Professor Blazko in Moscow proved it for RW Draconis, XZ Cygni and other Antalgol variables.

The writer has shown that there is a possibility for stars of the β Canis Majoris type and galactic Cepheids to be various expressions of the same phenomenon, the difference between the two types being chiefly related to density. Most stars of the β Canis Majoris type are of spectral class B or A dwarf with a density averaging 0.1 of the sun; the Antalgols are usually of class A or early F giant; while the galactic Cepheids are decidedly super-giant stars of classes F, G or K, with densities averaging perhaps 0.0001 of the sun.

Such being the case a pertinent question arises: might there be a double periodicity in phenomena exhibited by galactic Cepheids, revealed either as a centre-of-mass variation, or as an amplitude change or both?

Should the answer be affirmative, search for the cause of Cepheid variation would be led into a new channel. In this event the hypotheses that a Cepheid is a binary star having a period equal to that of the light-curve, or that it is a simple pulsating star, will have to be abandoned, because it might be more logical to consider a long period orbit in which the primary star exhibits light variations under the influence of rotation and tidal effects.

Very few complete radial velocity investigations of Cepheids have been made, since their apparent brightness is usually small; generally only sufficient observations have been secured during a short interval of time to determine one velocity curve.

In α Ursae Minoris and Y Sagittarii[3] a centre-of-mass velocity variation exists; from Albrecht's observations Dr. Ludendorff[4] pointed out that a variation of amplitude and perhaps also of centre-of-mass velocity is present in the case of Y Ophiuchi.

In the recent paper by Jacobsen[5]: "A Re-determination of the Radial Velocity Curves of certain Cepheid Variable Stars", based on three-prism spectrograms secured at the Lick Observatory, the first two conclusions are:—

"(1) In the case of the three Cepheids, δ Cephei, η Aquilae and ζ Geminorum, for which the radial velocity curves of the earlier

[3]Ap. J., Vol. 56, p. 373, 1922.
[4]A. N., Vol. 203, p. 368.
[5]L.O.B., Vol. 12, p. 138, 1926.

and later epochs were determined from three-prism observations, little or no change has been found in the form of the curves.

(2) The apparent difference in shape found in the velocity curve of W Sagittarii based upon comparing one-prism with three-prism observations may perhaps be partly accounted for by variation in blend effect with phase. It is, however, so large as to be probably real."

According to Jacobsen W Sagittarii is thus another addition to the list of double periodic galactic Cepheids.

RT Aurigae is another, as shown by Kiess[6] at the University of Michigan and confirmed by the writer from a series of new observations. Figure 5 shows the three velocity curves of RT Aurigae by Duncan in 1908, by Kiess in 1917 and by the writer in 1926.

But the important fact to be emphasized in this paper is that contrary to Jacobsen's first conclusion δ Cephei, the prototype of galactic Cepheids, also exhibits a double periodicity.

Series of spectrograms of δ Cephei were obtained here in 1923 and 1926, and its study is being continued.

Although our spectrograms are taken with a one-prism instrument, a very narrow slit was used and all possible tests of the instrument made regularly to insure that focus and temperature control were always perfect. Numerous sharp narrow lines are found on them and when they are measured on the spectrocomparator by different observers the velocities obtained agree within a few tenths of a kilometer.

Our velocity curve for 1923 agrees with that of Jacobsen, who by chance secured plates almost simultaneously. In Figure 6 Jacobsen's velocities are indicated by circles and ours by crosses.

A variation between this curve and Moore's curve obtained in 1907 was suspected.

Using the same standard spectrogram as for the 1923 plates, our observations of 1926 are plotted in Figure 7, and the curve drawn through them is noticeably different from that of 1923.

Dominion Observatory, Ottawa,
May 18, 1927.

[6]Pub. of the Obs. Univ. Mich., Vol. III, p. 131.

THE ELEVEN YEAR PERIOD IN SUNSPOTS APPARENTLY REFLECTED IN THE ANNUAL GROWTHS OF A PRE-GLACIAL SPRUCE*

By Ralph E. De Lury

Sections of Sitka spruce released by the recession of the Glacier in Tarr Inlet, northern British Columbia, were secured in 1925 by Mr. J. P. Forde, District Engineer of the Public Works Department, in the course of his investigations of this new channel to Canadian territory. He reported as a possibility that the ice may have covered these trees about 300,000 years ago, in accordance with the estimates made by geologists for one of the glaciations in this region.** It is known that trees exhibit in their yearly growths as measured by the rings, a periodicity accompanying the sunspot fluctuations of average length somewhat over eleven years; for example, Douglass has shown that the sequoias of California exhibit the effect back 3200 years. Consequently it is of interest to see if these pre-glacial spruces show in their annual rings a similar periodicity, especially since one of the theories of sunspots gives to them a comparatively recent origin. Chief Engineer K. M. Cameron of the Public Works Department kindly supplied the Observatory with a section for measurement.

The section was 7.1 in. by 5.7 in. (18 cm. by 14.5 cm.), and it had 170 annual rings. There were numerous fissures, and several embedded limbs. The ends were boiled in paraffin and smoothed by turning in a lathe. The smoothed surfaces were photographed and glass positives were made for measurement on one side of the Ottawa 12-inch spectrocomparator.

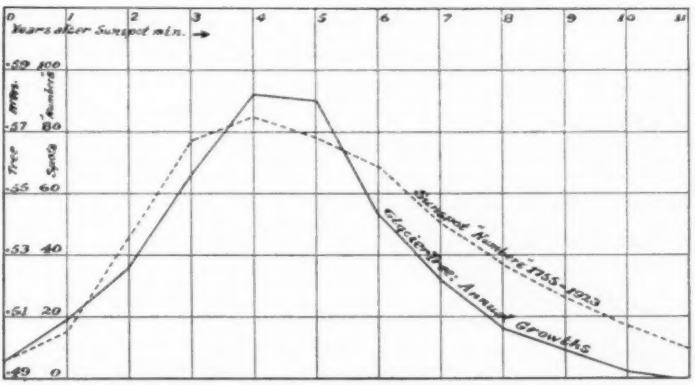
*Read before the Royal Society of Canada, May, 1927.

**The remains of forests which had grown on débris following more recent glaciations have also been revealed in neighboring regions, and the question of the time of growing of the specimen here considerd has not, as yet, been definitely estimated.

PRE-GLACIAL TREE-GROWTHS AND SUNSPOT NUMBERS

Radius	Years	0	1	2	3	4	5	6	7	8	9	10	11 yrs.
A90°	112	.614	.627	.622	.668	.735	.708	.645	.623	.624	.624	.606	.592 mm.
270°	115	.436	.450	.467	.472	.489	.498	.491	.477	.449	.428	.420	.429 mm.
B50°	90	.520	.542	.582	.677	.722	.704	.632	.539	.513	.560	.562	.510 mm.
90°	110	.463	.462	.469	.483	.513	.528	.503	.488	.484	.460	.441	.453 mm.
230°	100	.449	.464	.471	.481	.497	.507	.489	.460	.443	.434	.431	.435 mm.
Mean		.496	.509	.522	.556	.591	.589	.552	.517	.503	.501	.492	.484 mm.
Smoothed Mean		.496	.509	.527	.556	.582	.580	.542	.522	.506	.499	.492	.489 mm.
Sunspot Numbers		5.9	15.0	45.3	77.7	85.1	78.1	68.7	50.2	36.8	26.0	16.8	9.7

The upper end, A, (Plate VIII) of the section was measured along parts of the 90° and 270° radii, and the bottom end, B, (Plate IX), along parts of the 50°, 90° and 230° radii. To secure 11.5 year means the measurements in each case were arranged in 12 columns, the 12th being omitted in every other row. The means were smoothed by the usual formula, $0.25\ (a+2b+c)$, where b is the value for any column, and a and c for the preceding and following columns, respectively. These means are given in the accompanying Table, each



Curves showing correlation between annual growths in a Pre-glacial spruce and sun-spot numbers.

mean showing a decided resemblance to the 11.5 year curve of "sunspot numbers". The Figure shows the smoothed mean from the five measurements, together with the mean curve from 15 complete cycles of sunspots, 1755-1923. The phase, of course, is not known, but it may be inferred that maximum growth occurs at sunspot maximum.

It would thus appear that the sunspot influence was at work in the possibly very remote time when this spruce was growing. There are large trees growing at the present time on some of the glaciers. A thorough investigation of the growths of the living trees as well as of some of the largest of the pre-glacial trees is advisable. Mr. Forde has kindly suggested that he may secure further specimens during the coming summer.

Dominion Observatory,
Ottawa, May, 1927.

SOLAR RECORDS IN TREE GROWTH[1]

By A. E. Douglass

THE freedom from undergrowth of the pine trees of northern Arizona and their exposure to the characteristic droughts of the country first suggested to the writer the idea that their variations in growth had a climatic and solar origin. Accordingly a long search was made for evidence of such relationship, which has resulted in the identification, dating and measurement of several hundred thousand rings in something under a thousand trees scattered widely about this and other countries. Many interesting results have been obtained and an extensive technique of ring-study has been developed. Of that technique the most important line has been the study of cycles which might have a solar cause.

It is no surprise that variations in climate can be read in the growth rings of trees, for the tree ring itself is a climatic product. In the spring the pines put on a rapid growth of soft white tissue, which continues till lack of moisture, through temperature or dryness, diminishes the growth and stimulates the tree to prepare for winter by putting on a red lignite ring. The growth gradually stops and in sufficiently dry or cold weather comes to an end till the warmth and moisture of spring revive it.

If successive years were exactly alike, the rings would all be of the same size with some alteration with age or injury. But successive years are not alike, and in that difference some factors appeal strongly to the trees. In northern Arizona, with its limited moisture and great freedom from pests and with no dense vegetable population, this controlling factor is identified as rainfall. So it is not astonishing that the pine trees, as tested near Prescott, Arizona, show a correlation with rainfall between 80 per cent. and 85 per cent.

[1]Address of the retiring vice-president of Section D—Astronomy—American Association for the Advancement of Science, Philadelphia, December 29, 1926. Printed in "Science," March 4, 1927.

The extent of the dependence of this southwestern rainfall on solar changes is still a point under discussion. Helmann found the sunspot cycle in the rainfall of North Germany, and it has been identified in many places, most notably perhaps in the well-known thirty-five-year Brückner cycle. But the strongest bit of evidence of solar effect on climate is in the trees themselves, for in this region where the trees are specially sensitive to rainfall they show the eleven-year sunspot cycle in a striking manner, and they show it in a double-crested curve just as the rainfall itself in southern California shows it. This has been brought out recently in a dramatic manner. From the start the sunspot cycle was sought in the Arizona pines, and during long parts of their growth it seemed perfectly evident, yet for scores of years it failed, and in 1914 I very nearly gave up the idea that the trees really show it, because near 1700 it failed entirely. Finally in 1919 (Carnegie Publication 289) I gave the facts about it, saying that from 1660 to 1720 the sunspot curve "flattens out in a striking manner," and again, "the sequoias show strikingly the flattening of the curve from 1670 or 1680 to 1727." Early in 1922 I received a letter from Professor E. W. Maunder, of England, calling attention to the prolonged dearth of sunspots between 1645 and 1715 and saying that if there were a connection between solar activity and the weather and tree growth, this extended minimum should show in the weather and in the trees. On receipt of the letter this period was immediately recognized as the interval referred to in which there was entire failure in attempting to trace solar effects. A more recent review of the eleven-year period in those trees confirms its well-marked existence from before 1400 to the middle of the seventeenth century. Soon after 1700 it reappears, but not in complete form until the latter part of that century.

The test was then carried to the sequoias. It was found that the slow-growing sensitive upland trees were the ones which best displayed the solar cycle, and also that the interference by other cycles was such that the double period of about twenty-three years was a more satisfactory manner of tracing the changes of the solar period. When these conditions were allowed for, the same result was obtained as before from Arizona.

In 1922 or before, it was noticed that when the eleven-year cycle disappeared from the trees near 1700, two other cycles, one of ten or twenty years and the other of fourteen or twenty-eight years, became prominent in its place in the Arizona pines. Soon after it was noticed that the Vermont hemlocks show the same change at that time, and so also the sequoias of California. And then it was observed that these three basic cycles appear generally in the western trees; these are, first, eleven and one half or twenty-three years; second, ten or twenty years; and, third, fourteen or twenty-eight years. And these three cycles were recently confirmed in a study of 52,000 measures of rings in 305 trees scattered over ten western mountain states. And there is reason to think that all these cycles come from the sun, for at different times the sunspot cycle itself has changed to one or the other of them. For example, from 1748 to 1788 there were four complete cycles of ten years each; from 1788 to 1830, forty-two years, there were three complete cycles of about fourteen years each. It seems at least likely that these other two cycles, found in western trees with extraordinary persistence, are also of solar origin.

In the recent extensive study of cycles in the western yellow pine, it was noted that the moist coastal regions show the eleven-year cycle more generally than the drier interior sections or the Rocky Mountain area. This agrees with the result of ten years ago in which the wet-climate Scotch pines of North Europe, especially near the Baltic Sea, showed a direct single-crested sunspot cycle having a remarkable resemblance to the curve of sunspot numbers. Their growth gave the solar changes with an accuracy exceeding that of any trees of the southwestern area. Recent study confirms the further statement that this is a wet-climate phenomenon. But it is not yet clear just what causes this accuracy of record in the wet-climate trees. It seems probable that the wet-climate trees follow the sunspot cycle more closely than do the weather elements in which they live, and it is perhaps safe to repeat the suggestion made by the writer in 1922 that there may be some more direct line of cause and effect from the sun to these trees than we have taken into account, such, for example, as radiation (possibly of short wave length), that is especially favorable to trees growing

generally under cloudy skies. In tree groups along the Atlantic coast of this continent, the eleven-year cycle is also prominent, but it has a phase displacement of two or three years.

The pages above give the probable forms which solar records take in tree growth. It was expected by the time of this writing to have a fairly complete historic study of solar variations, but the formal work along that line has had to be postponed for a time. In a general way it is safe to say that the sunspot cycle and its double and triple value are very general. The double value has persisted in Arizona for five hundred years and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Brückner's cycle, has operated in Arizona for the last two hundred years and in Norway for four hundred at least. A hundred-year cycle is very prominent throughout the three thousand years of sequoia records and also in the five hundred years of yellow pine. It is still uncertain whether the eleven-year cycle can be judged by the variations in its double value, which, from the absences of certain interfering periods, is more easily traced through long periods. But a very incomplete review of the sequoia record suggests that from 1300 B. C. to well after 1000 B. C. the eleven-year cycle was well developed; then it slowly decreased. From 300 B. C. on it was increasing and was very conspicuous during the first two centuries of our era. Then it decreased, and from 400 to 650 A. D. was only occasionally evident. From 650 to 850 or 900 it seems fairly continuous. Then it appears only occasionally until about 1250, when it again becomes fairly continuous, except for the changes in the seventeenth century above noted.

Such then are the solar records so far translated from tree growth, whose complete understanding, it is believed, will give us extensive historical information of this sort in many different parts of the world.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The Eclipse of June 29

The total eclipse of the sun occurred in the northern part of England just after sunrise on June 29, and in Norway when the sun's altitude was about 10°.

The present writer was pleased to learn that in several places in England, especially at Giggleswick, Yorkshire, where the Astronomer Royal's party was, the eclipse was comparatively well seen and some very good photographs of the inner corona and the many prominences visible were taken. From London and Liverpool newspapers, which were sent by kind friends, it is seen that much interest had been aroused in the phenomenon, and the reproductions of some of the pictures are very well made (?).

In Norway, where the forecast for a clear sky was much more promising than in England, dark clouds prevented any observations, much to the regret of all.

The Work of the Lowell Observatory

In the *Publications of the Astronomical Society of the Pacific* for June 1927 is an interesting outline of the history and the work of the Lowell Observatory by its director, Dr. V. M. Slipher. It was founded in 1894 by Dr. Percival Lowell who vigorously directed it during his lifetime (d. 1916) and who gathered about him a company of able co-workers.

The Observatory is about 1½ miles west of Flagstaff, Arizona, and is 7250 feet above sea level. Its chief instruments are a 24-inch refractor and a 42-inch reflector, while a 15-inch reflector is mounted 10 miles away at an elevation of 11,500 feet.

Lowell's main object was to study Mars and the other planets and an immense amount of research of the highest quality has been done on them. At first many of Lowell's conclusions were not favorably received by other astronomers, but as the years go by they are being continually confirmed. Dr. Slipher and his associates, however, have not limited their sphere of action to the solar

system, and their investigations into the nebulae have been exceptionally valuable. In particular might be mentioned the determination of the radial and rotational velocities of the nebulae.

There has just been published an account of the measurement of the radiation from Mars during the 1926 opposition by Coblentz and Lampland. This verified and extended the observations in 1922 and 1924. This research has been very laborious and difficult; but the results obtained have been rendered more definite and trustworthy, and they have been largely corroborated at Mount Wilson. Dr. Slipher says: "The measures show the temperature, near the centre of the disc, in cases to reach 30 to 40° C. (86 to 104° F.), to be higher in the afternoon than in the forenoon, of dark regions to be higher than light ones, and its seasonal change over the planet to be clearly disclosed."

On reading the very condensed account given here, the thought comes that if the information gathered at this Observatory was combined with that obtained at one or two others during the last twenty-five years a remarkable book on our planetary system could be produced.

NEWTON AND LAPLACE

The bi-centenary of Newton's death has been celebrated on numerous noteworthy occasions during this year: but along with it the Société Astronomique de France coupled the centenary of the death of Laplace who was the most illustrious "continuator" of his work. It was in France during the eighteenth century that one finds the most eminent successors of Newton—Clairaut, d'Alembert, Lagrange and Laplace.

Pierre-Simon Laplace was born on March 23, 1749 and died March 5, 1827. His life was largely devoted to science. One of his first researches was on the stability of the solar system (1773). This was followed by numerous others on the motions of the planets and their interactions, and his great monument was the "Mécanique céleste".

In 1795 at the foundation of the National Institute of Sciences and Arts, Laplace and Lagrange were named members of the mathematical section. His relations with Bonaparte led to his being named Minister of the Interior, but he soon relinquished the

office which was not to his taste. The reputation of Laplace was very great. It is related that Lagrange, when examining a young mathematician who had offered a paper to the Institute, asked him why in it he had referred to Laplace, who had not written anything on the subject at all. The reply was: "I was told that I would have no chance at all unless I referred to Laplace."

It was in a short note to his "System of the World" that Laplace outlined the nebular hypothesis of the solar system in the form which became so familiar but which is now discarded.

It is reported that Laplace's last words were: "That which we know is very small, that which we do not know is immense". This seems an echo of Newton's famous words about the child picking up pebbles upon the shore of the unexplored ocean.

C. A. C.

THE MOON AND THE WEATHER.

An article in *Science News-Letter* by Professor W. J. Humphreys, *The Moon and the Weather*, deals with this subject in a very clear and capable manner, and it may be useful to have at hand some of the arguments which he brings forward and so his discussion is printed herewith.

If you ever had the good fortune to live in the country, or even to spend a few summers in the mountains, you surely are familiar with the confident assertion that as soon as the moon changes the weather will get better. If the fields are parched, there will be rain when the moon changes; if they are too wet the change of the moon will bring fair weather and clear skies. Whatever you want in the way of weather, that, they tell us, you will get, when the moon changes—a cheery, hopeful expectation inherited from grand-dad's grand-dad, an ancient legacy of faith, misplaced to be sure, but so comforting that it were a pity to destroy it, if we had nothing so good or better to offer in its stead. But let us destroy it, for really the moon does not control the weather, and there are indeed much better guides to follow than the olden tradition that it does.

But how do you know, the faithful ask and have a right to ask, that the moon does not influence the weather? It is certain that the great tides of the ocean are caused mainly by the moon; and even the continents, mountains and all, are raised and lowered, twice a day, nearly a foot by the tug of the moon. Surely, then, so the moon advocates insist, the tides of the light, mobile atmosphere must be many times larger—so large indeed as to produce great changes in the weather. All this appears very reasonable, we must admit, but it happens that the atmosphere does not behave

that way, and so far from it, indeed, that its tides are so minute that they can be detected only by the most searching and delicate means. We must give up the idea, then, that the moon pulls the atmosphere about in great ebbs and flows, and thereby affects the weather—must give it up, because, on careful examination, we find that nothing of the kind happens.

But how about the heat from the moon, our friends, the faithful, inquire with good reason; isn't that greater at full moon than at new moon, and enough greater to change the weather? yes, we must answer, it is greatest at full moon, but even then, as shown by direct measurement of the moon's radiation, so small that it can alter the temperature of the earth by only one or two thousandths of a degree, a change so trivial that no one could be certain of it, nor would take any account of it if he were. In quite a different, and hidden, indirect manner, however, the moon changes the temperature of the earth manyfold as much as by its own conspicuous radiation. It does so in this way: Since both it and the earth swing around the sun together, and at the same time rotate about each other like a big weight and a little weight at the two ends of a stick hurtling end over end through the air, it follows that at full moon, the time when the moon is on the opposite side of the earth from the sun, the earth itself is closest to the sun, and at new moon farthest away. This action of the moon changes, between full moon and new moon, the distance of the earth from the sun by about 6,000 miles. That is, at full moon the earth on the average is about 6,000 miles nearer the sun than it is at the time of new moon. Well then, says our moon friend, if you change your distance from the fire that heats you by 6,000 miles, surely you will make a big change in your temperature. Truly, 6,000 miles seems a long way when thought of in terms of travelling over the face of the earth, but it is a mighty little part of our 90-odd million miles from the sun, and the temperature effect of this relatively small change in the total distance from our great source of heat is correspondingly minute, in fact only about one-fiftieth of a degree, far less than one measures on any ordinary thermometer, and much too small to be noticed in connection with the weather.

Perhaps, now, our moon champion will offer another and very pretty bit of evidence in favor of the idea that the moon greatly affects the weather. Why, he says, many a time I have seen the moon just eating up the clouds. The sky was nearly covered with clouds at sundown, and then in less than an hour the moon was shining bright and there scarcely was a cloud to be seen. The moon had devoured them all, and surely we must agree that the weather is different under a clear sky from what it is under a cloudy one. Of course, we agree to that, for the difference is very real, and we agree, too, to the statement that often a sky that is considerably clouded at and before sunset is *seen*, during the light of the moon, to clear off rapidly as the twilight deepens. But we do not admit

that the moon had anything to do with causing the clouds to disappear. It just enabled us better to see them getting smaller and fewer and farther between. This is how it all comes about: When the sun goes down, clouds cool faster than the dry air. They lose heat and also chill the air they are in. This chilled air contracts, as cooled things do, becomes correspondingly denser, and sinks to lower levels, pulling the cloud particles along with it. As it sinks it gets warmer and warmer, and stops sinking and warming only when it comes to the same temperature as the air that surrounds it. Now, as the sinking air gets warmer, of course the cloud droplets in it evaporate and the cloud disappears. The whole process is very simple and evidently happens just as well when the moon is below the horizon as when it is above. The difference is with ourselves. We don't see so clearly the vanishing of clouds on a dark night as on a bright one. In fact, we scarcely see it at all except when there is a moon to make the clouds distinctly visible. And so it happens that we mistakenly attribute the disappearance of the clouds to some action peculiar to the moon, when as just explained, the moon has nothing to do with it.

The moon then does not make big tides in the air; it does not in any way appreciably affect the temperature of the atmosphere; and although it seems to dissipate clouds—to eat them up, as we say—it does nothing of the kind. We are sure, therefore, after all this, that the moon does not noticeably control the weather. But our moon friend is not so sure of it. In fact, he is not sure of it at all, and frankly tells us that no matter what our argument the real proof of the pudding is in the eating, and he is absolutely certain that when the moon changes the weather changes, and that it seldom changes without a change of the moon. In both these cases he is absolutely right, not because the moon changes the weather, but because as both are always changing they have to change together. You see, there are only about 28 days from new moon to new moon, and in that time the moon shows four changes, as they ordinarily are counted, that is, first quarter, full moon, third quarter, and new moon; in short, one change every seven days. Besides, these changes are not abrupt affairs, but, as we usually observe and note them, each is spread over at least two or three days. Then, too, those who forecast the weather in this manner generally give it a leeway of a few days in which to make good. Our moon friend, therefore, however honest his belief, really is playing the game of "heads I win, tails you lose," for as all the time is used up, it would be impossible to find any date on which a change of the weather could occur without being close to some change or other of the moon.

Well, then, if we can't trust the change of the moon to bring a change of the weather, what can we trust? We can trust two things: In the first place, weather commonly goes in short spells, at least over the more densely populated portions of the temperate zones. That makes for

abundant vegetation and good crops—one reason why these places are densely populated. Here the weather usually is fair a few days, and then cloudy to foul for a day or two. This is the rule, and so whatever the weather, it is apt but not certain, to change some time soon, but not for long—another change will quickly come, and others without end. The second thing we can trust in this connection, not as an infallible guide, but as by far the best we have, is the official forecast of the coming weather issued by the Weather Bureau. These forecasts are not infallible, as just stated, but their failures nearly always concern trivial matters. When a cold wave, a killing frost, a destructive hurricane, a devastating flood, or any other major weather phenomenon of real importance is officially predicted it is practically certain that the prediction will be 100 per cent. correct.

But, says our friend, what about dry moons and wet moons, that tell us what sort of weather we are going to have for nearly a whole month? You know, he says, that when both horns of the new moon point up it can hold lots of water without spilling, and therefore brings enough to furnish a dozen rains or more. On the other hand, when the new moon stands on end, or nearly so, it is a dry moon. It can hold but little water, and, of course, for the next three or four weeks there will be very few rains, and even these will be light. Yes, we tell him, we heard all that long ago, and we also heard forecasts and explanations just the reverse of his: That is, we heard some people say, as he does, that when both horns of the new moon point up there will be lots of rain; and we heard others say, just as positively, that the whole month will be dry, because when both horns are turned up, very little water can spill out. Similarly, these others called the tilted new moon wet and not dry, because being tilted it must spill out abundant rains. In short, while the moon weather-prophets all agree that there is a wet moon and a dry moon they differ completely as to which is which; what the one insists is a dry moon the other declares to be a wet moon, and what the first calls a wet moon the second calls a dry moon. Each is wholly wrong, but their average is exactly right, for there is no wet moon and no dry moon. If there were, then since the pointing of the new moon's horns is the same everywhere along any parallel of latitude, wet spells and dry spells would not be scattered irregularly over the earth as they actually are, but form continuous belts around the world, which certainly they do not. Furthermore, careful studies of the records kept at hundreds of weather stations all over the earth show that neither the pointing of the new moon's horns, nor any of the moon's changes, has the slightest relation to warm weather or cold, wet or dry, fair or foul.

The moon is a wonderful theme in song and story, in love and war, in sentiment and science, but for all that it never did, and it never will, have anything to do with causing or changing the weather.

MEETINGS OF THE SOCIETY

AT OTTAWA

A social gathering of the members of the Royal Astronomical Society (Ottawa Centre) and their friends was held at the Dominion Observatory on Wednesday evening April 20th, when through the kindness of the Director and his staff the various instruments of the Observatory were shown and their uses explained.

In the basement of the building are the earthquake instruments. The Wiechert vertical seismograph was used to demonstrate the method of determining the distance to the origin of an earthquake and the time of its occurrence. Several seismograms showed the records obtained at Ottawa of some of the more recent destructive earthquakes.

The Solar Physics Laboratory is also in the basement and the coelostat telescope with the reflector extends beyond the building, partly underground. Photographic plates and prints showed the spectra observed, and other series showed the rotation of the sun, the transit of Mercury, and a partial eclipse of the sun. The solar measuring machine, designed and built at the Observatory, was shown, for direct measuring of spectra as well as for comparisons. A section of pre-glacial Sitka spruce (found in 1925 in Northern B.C., where it was exposed by the recession of the glacier) was exhibited with a chart of the measurement of the annual rings which showed the influence of the 11.5-year sunspot cycle in pre-glacial days.

In the Gravity Section two instruments were shown. The three pendulums and the pendulum apparatus are used in determinations of gravity throughout Canada, and the Foucault pendulum suspended from a support thirty feet high illustrated the rotation of the earth. An accompanying map showed the results of 69 gravity stations in Western Canada.

Many lantern slides were shown covering a wide range of subjects and a demonstration of the enlarging camera was given.

The Terrestrial Magnetism instruments consisted of those used in determining the three magnetic elements—declination, inclination, and horizontal intensity. A map showed the magnetic stations occupied since 1907 and views of magnetic stations were displayed.

Many Indian and Eskimo curios were on exhibit. These valuable specimens of native work were collected while on magnetic surveys, and are representative of the work of tribes scattered from Labrador to the Yukon.

The method of measuring star positions with the meridian circle, a telescope of the greatest precision, was shown and the determination of accurate time

illustrated. In this division the time service, which radiates all over the departmental buildings, has its source. The different clocks and other instruments connected with the time service, the computing machines, and the method of sending out time were exhibited and explained in a very interesting and instructive manner.

The Department of Astrophysics provided several exhibits. In the office were to be found photographs of stellar spectra of different types and the measuring machines for spectrograms, the usual computing machines, and an arrangement to illustrate the principles of spectroscopy, by means of which it was possible to view the light emitted by a single element separated into its constituent colours or wave-lengths. At the same time the 15-inch equatorial telescope in the main dome was at the service of the visitors and a programme was shown consisting of the most interesting sights visible at this season, including planets, stars, double stars, and star clusters.

In the wireless room demonstrations were given of long and short-wave signals, pen recording on drum chronographs, audio band selective amplifier, syphon recorder and relay for high speed recording. Field receiving sets were exhibited, and Warren synchronous household and office clocks run and kept in step with an electric light supply and correct time.

Experiments were made showing Hertzian bulbs and interaction among aerials which break up into harmonics exploring field regions for loops and nodes of waves.

In the Stellar Photometry Division was the measuring engine for determining the diameters of star images on the photographic plate, measurements being made as fine as one ten thousandth of a millimetre. Here also was the Hartmann photometer for measuring the densities of star images, this machine giving very accurate measurements of star magnitudes with an error of only a few hundredths.

There was an interesting exhibit of a collection of over one hundred lantern slides, covering many phases of astronomy, from the original equipment of the Ottawa Observatory on Cliff Street, to the modern giant telescope at Victoria, B.C., and from our close neighbour, the Moon, to the Spiral Nebulæ or Island Universe far beyond our Milky Way.

Many of the visitors took the opportunity to inspect the library, consisting of some 15,000 volumes on astronomy and allied sciences. These include scientific periodicals and publications from the chief observatories of the world.

Many of the visitors commented on the cramped condition of the library and the great need for further accommodation.

The collection of some 1500 lantern slides attracted considerable interest, and samples of these were on display in other parts of the building.

A. H. Hawkins,
Secretary

The Royal Astronomical Society of Canada

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